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**JOINT ADVANCED WARFIGHTING SCHOOL**



**Military Aircraft Modernization: A Better Solution to Managing  
the Fighter Shortfall - the Sole Answer is NOT the F-35 Program**

**By**

**Daryl E. Trent**  
*Commander, United States Navy*

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Shortfall - the Sole Answer is NOT the F-35 Program**

by

**Daryl E. Trent**

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**A paper submitted to the Faculty of the Joint Advanced Warfighting School is partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.**

**This paper is entirely my own work except as documented in footnotes.**

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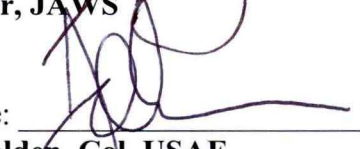
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## **ABSTRACT**

The F-35 Lightning II is a 5th generation, multi-service, multi-national capable Joint Strike Fighter (JSF) aircraft built by the Lockheed Martin Company. The Lightning II is a dual (Strike-Fighter) role aircraft designed to operate as an all-weather interceptor and ground attack capable platform. This study examines the feasibility of investing two decades worth of effort to build the most advanced fighter ever employed and questions whether additional funds should be spent on incremental platform upgrades to legacy aircraft. The Joint Strike Fighter program has quickly approached a \$400 billion price tag, with a cradle to grave price cost estimated between 1-1.5 trillion dollars. Conversely, the Lockheed Martin F-22 Raptor was the first 5<sup>th</sup> generation fighter and is the single most advanced and capable air-to-air platform in existence, but production was cancelled in 2009 and stopped at 187 aircraft well short of the 750 originally planned. The F-22 is an air superiority aircraft that greatly compliments the F-35, however, too few were authorized to fully support the role it was developed to engage.

Is DOD getting the best suite of combat aircraft for the money it is spending? More specifically, is the U.S. procuring too many F-35's when some of those funds could be used to improve legacy aircraft? Should the F-22 production line be reopened even if the unit cost is significantly higher? Furthermore, there is

concern that many of the F-35's advanced capabilities have already been stolen by China, placing its exorbitant cost even further in question. There has been much speculation how China built only its second indigenous aircraft so quickly yet it clearly resembles the F-35. Many have speculated China engaged in corporate espionage and stole trade secrets. The U.S. needs to shore up their leaks and maintain better custody of their secrets if they wish to maintain a tactical advantage against their enemies.

This study argues that the F-35 alone is not the sole answer to U.S. problems when it comes to air superiority. A compliment of F-35 and F-22 aircraft in a high-low configuration is a better fit to ensure lethality in the air superiority arena. Secondly, a mixture of legacy aircraft is essential so as not to put all the nation's strike fighter defenses into a single point of potential failure, one that may be already compromised. Additionally, maintaining cheaper, albeit less capable, platforms such as the A-10 and F-16 for certain roles preserves expensive assets while placing a more survivable platform in a contested ground support role. The U.S. cannot afford to compromise future concept development when it comes to advanced fighters, but the U.S. will likely continue to engage a low-technological enemy for decades to come. In the end, a mixture of legacy aircraft with continued support for incremental improvements complimented with a reduced purchase of Joint Strike Fighters appears to be a better fit today and into the next thirty years.

## **DEDICATION**

To my family – without your support and understanding I would have never been able to complete my research and deadlines. The dining room table is now yours again. Thank you!

To Dr. Bryon Greenwald and Col Doug Golden - Thank you for your guidance, advice, and assistance during this undertaking. Your vectors to keep this project on course enabled me to look at this problem from a completely different angle of attack. Thank you both!



## CHAPTER 1: INTRODUCTION

Over the last quarter century of fighting, the United States has enjoyed an overwhelming advantage in military aviation technology.<sup>1</sup> The U.S. leads the international community in military aircraft Research, Development, Test and Evaluation (RDT&E), while fielding the most sophisticated military aircraft in the world.<sup>2</sup> With a defense budget that exceeds the next eight largest militaries, the U.S. remains the world's leader in aviation research and development.<sup>3</sup> The FY2016 National Defense Authorization Act approved a Department of Defense (DOD) combined base and Overseas Contingency Operations (OCO) budget of \$580.3 billion.<sup>4</sup> Within the combined budget, \$112 billion was approved for

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<sup>1</sup> Development of advanced aircraft to compete on the world stage is critical to the United States maintaining a tactical advantage on the future battlefield. At no point does the author believe that research and development for advanced aircraft should stop. The argument is being presented that the amount of new aircraft purchased should be limited in scope and the funds not expended on the F-35 could be better invested developing enhancement capabilities on proven legacy aircraft. The term "modernization" used throughout this document means the development of a completely new aircraft such as the F-35 from research and development through fleet implementation. The term "incremental improvement" used in this document means the modification made to an existing aircraft to improve the capability or prolong the life of an aircraft.

<sup>2</sup>OEDC Data, "Gross Domestic Spending on R&D," <https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm> (accessed October 03, 2016).

<sup>3</sup>Glenn Kessler, Michelle Ye Hee Lee, "Fact Checking The State of The Union." Chicago Tribune. <http://www.chicagotribune.com/news/nationworld/ct-fact-check-state-of-the-union-20160112-story.html> (accessed February 03, 2017).

<sup>4</sup> To make equal comparisons of the various programs within the DOD budget, the author used the 2016 enacted defense budget base figure of \$521.7 billion combined with the OCO budget of \$58.6 billion for a sum of \$580.3. To accurately compare available data, it was necessary to combine figures since the sum of the base, OCO, procurement and R&D were used when comparing aircraft data. Nowhere during the research of this project could the author find a single figure the government invested strictly in military aviation RDT&E. RDT&E funds are complex and can be parsed many ways, to prevent inaccurate interpretation of the figures found in Title IV of the annual defense appropriations act, broader numbers will be used to represent the data more accurately.

procurement costs to be used across all military service components within DOD. Additionally, \$69 billion of the 2016 combined budget was set aside for RDT&E across DOD. Within that 2016 DOD RDT&E budget, \$1.8 billion was set aside strictly for F-35 research and development.<sup>5</sup> The collective investment in the F-35 program in contrast is staggering. Referencing Table 1, the amount of funds dedicated for F-35 RDT&E is 40% greater than the combined sum of all other fixed wing RDT&E military aircraft currently in procurement, while the total cost of procurement for the F-35 is basically equal to all other active procurements combined.

Table 1. RDT&E and procurement costs per aviation platform, 2016

FY-2016						
	Platform	RDT&E	Procurement	No A/C	Total Cost	Unit Cost
1	F-35	\$1,854.3	\$8,747.9	57	\$11,012.4	\$193.2
2	P-8A	\$142.3	\$3,278.4	16	\$3,422.2	\$213.8
3	KC-46A	\$602.4	\$2,350.6	12	\$3,008.0	\$250.6
4	C-130J	\$41.8	\$2,321.6	29	\$2,580.0	\$88.9
5	V-22	\$95.5	\$1,480.2	19	\$1,582.4	\$83.2
6	E-2D	\$272.1	\$1,033.4	5	\$1,313.2	\$262.64

Source: Data from Office of Under Secretary of Defense Comptroller (CFO) FY-2016 Program Acquisition Cost by Weapon System. Research, Development, Test and Evaluation (RDT&E) All monetary figures are in millions of dollars.

<sup>5</sup> American Association for the Advancement of Science, "The President's FY 2016 Budget," <https://www.aaas.org/fy16budget/federal-rd-fy-2016-budget-overview> (accessed October 03, 2016).

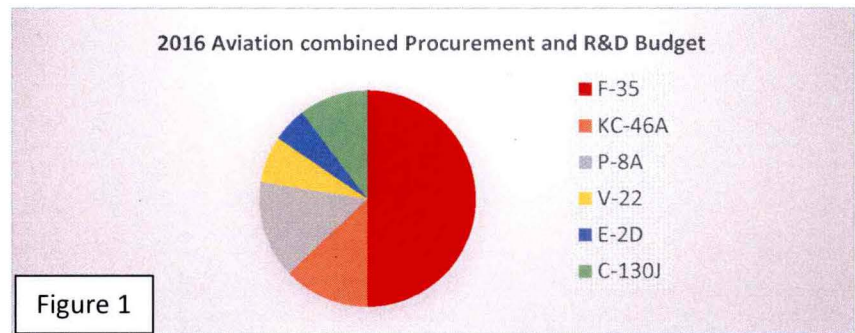
Given the exorbitant amount spent to field the F-35 across all services, is DOD getting the best suite of combat aircraft for the money it is spending? More specifically, is the U.S. procuring too many F-35's when some of those funds could be used to improve legacy aircraft? The argument presented here will examine the merits of the F-35 procurement program in contrast to utilizing those defense funds to buy a reduced number of F-35 aircraft. Furthermore, would investing more in an incremental improvement program for legacy platforms such as the F-22, A-10, F/A-18 and F-16 better capitalize upon leading edge technology to quickly provide the warfighter a viable and proven platform and be a better expenditure of limited defense funds? There are four reasons the U.S. should invest in incremental improvements as compared to simply flooding the fleet with a new, unproven platform that suffers from technical challenges at every turn. First, meeting the requirement to fill the 2,400 F-35 order continues to be met with delays resulting in legacy aircraft being extended beyond their expected service life. Secondly, the F-22 is a proven fifth-generation fighter that is a superior air superiority platform when compared to the F-35. Next, the F-35 lacks the ability to provide adequate "high" cover in a near-peer contested air-to-air arena. Finally, the F-35 lacks survivability in a Close Air Support role and is much more expensive to repair when battle damage is sustained as compared to more capable and cheaper platforms such as the A-10 and the F-16. Additionally,



this paper will examine near-peer competitor concerns with China and its ability to close the fifth- generation fighter gap the U.S. thought they once enjoyed.

### Sticker Shock

According to testimony before the U.S. Senate Armed Services Committee, acquisition costs for the 5th generation Lockheed Martin F-35 Lightning II Joint Strike Fighter (JSF) program is approaching \$400 billion, with a cradle to grave price tag estimated between 1-1.5 trillion dollars.<sup>6</sup> At one



billion dollars a copy, the B-2A Spirit, also informally referred to as the “Stealth Bomber,” carries the title of the single most expensive aircraft per unit cost. At current projections, the cost of the F-35 will eclipse that of the B-2A and make it the single most expensive defense project in history.<sup>7</sup> If the JSF acquisition program proceeds as envisioned, the U.S. military will phase out proven workhorses such as the A-10, F-16, F/A-18 and the AV-8, potentially jeopardizing national security by relying on single point failure, a single, unproven airframe plagued with delays and complications.

<sup>6</sup> Michael J. Sullivan, "F-35 Joint Strike Fighter." GAO Reports (April 26, 2016): 1-4, <http://www.gao.gov/products/GAO-16-634T> (accessed October 01, 2016).

<sup>7</sup> "Opening Statement by SASC Chairman John McCain on the F-35 Joint Strike Fighter Program." States News Service, April 26, 2016. <https://www.mccain.senate.gov/public/index.cfm/2016/4/opening-statement-by-sasc-chairman-john-mccain-on-the-f-35-joint-strike-fighter-program> (accessed October 6, 2016).

The F-35 defense acquisition program is nearly breaking the USAF budget as compared to upgrading existing aircraft platforms.<sup>8</sup> In stark comparison, upgraded advanced avionic weapon systems engineered for the B-52, A-10 and F-16 have kept costs down while fielding viable assets used today to assist with the low-tech conflict resolution in Iraq and Syria. Although the aforementioned aircraft have lasted longer than originally planned, the upgrades installed on these aircraft over the years make them just as feasible on the battlefield today in a U.S. dominated air superiority environment as when they were first introduced. Placing so much financial capital into a single program like the F-35 in today's uncertain funding climate without consideration of service life extensions and incremental improvement programs is reckless and may ultimately jeopardize national security, particularly if further budget cuts result in aircraft shortfalls. Combat aircraft across the U.S. military are already being forced to exceed the originally planned aircraft service life, which will further exacerbate a fighter shortfall if the F-35 continues to experience further delays.

### **Too Soon?**

Sadly, even though the F-35 program is plagued with problems, wildly over budget, and overdue, DOD has seen fit to fund research into a 6<sup>th</sup> generation fighter. Under Secretary of Defense for Acquisition, Technology, and Logistics

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<sup>8</sup>David Francis, How DoDs 1.5 Trillion F-35 Broke the Air Force. 31 Jul 2014 <http://www.cnbc.com/2014/07/31/how-dods-15-trillion-f-35-broke-the-air-force.html> (accessed 03 October 2016).

(OUSD(AT&L)), Frank Kendall has stated, "Right now [F-35] is coming to the end of its development phase, so part of this is to keep those design teams that do that kind of work engaged, doing meaningful work; move the technology forward; reduce the lead time to the next generation of capabilities.<sup>9</sup> In a program that is plagued with cost overruns and design flaws, and was supposed to be "combat capable" by 2010, this aircraft is late and has yet to deliver on most of its promises thus far. While the amount of R&D funding for a 6<sup>th</sup> generation aircraft is undetermined, if the lessons from the F-35 acquisition debacle are not appropriately heeded, there is a strong chance that the 1-1.5 trillion dollars "cradle to grave" cost necessary to support the F-35 will likely pale in comparison to what the U.S. can expect to pay for the next generation fighter.<sup>10</sup> Kendall secured funding for the FY-16 budget and is quoted as saying Defense Advanced Research Projects Agency (DARPA) has been considering 6th Generation fighter technology for a few years.<sup>11</sup> Hopefully, his office has compiled copious lessons learned from the F-35 experience and is offering those to the acquisition community as an example how not to run a program.

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<sup>9</sup> Megan Eckstein, "Kendall Announced Aerospace Innovation Initiative to Support 6th-Generation Fighter Jet," Defense Daily 265, no. 18 (January 29, 2015); 2. International Security & Counter Terrorism Reference Center, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=5&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=101027070&db=tsh> (accessed October 03, 2016).

<sup>10</sup> Ibid.

<sup>11</sup> Aaron Mehta, "USAF Vice Chief to Scientists: 'Help Us'", Defense News, January 28, 2015, <http://www.defensenews.com/story/defense/air-space/air-force/2015/01/28/usaf-spencer-scientific-advisory-board/22468731/> (accessed October 4, 2016).



In contrast to spending a significant portion of the defense budget on a single program such as the F-35, the United States should focus more attention against the threats it will face. Expanding legacy programs to extend the life of the platform while making it relevant on the modern battlefield may be a better compromise than placing all the offensive capability into a single platform. Focusing attention on how to develop incremental improvements to existing platforms that have a performance record to build upon may provide a better offensive and defensive capability. Furthermore, the argument can be made that weapon system testing from a known capability will rapidly decrease the amount of developmental and operational testing necessary to produce a fielded system to the warfighter, maybe in quarters or years, but not decades. This is not to say that a portion of the defense budget should not be set aside for research and development of new aircraft platforms, quite the contrary. With interwoven economies, the odds of a major conflict with a near-peer adversary such as China are unlikely, but must not be completely discounted. The United States still needs to develop advanced weapons that are agile and innovative to compete against our rivals, but on a much more reduced scale and scope.

### **Lessons from World War II**

When the British were confronted with a need for more aircraft during World War II, they attempted to secure additional aircraft by negotiating with American aircraft manufacture Curtiss-Wright Corporation. The Curtiss-Wright



Corporation rejected the offer by the British. Desperate to add fighters to the depleted Royal Air Force, the United Kingdom turned to a small American aircraft company by the name of North American Aviation. North American specialized in developing trainer aircraft and did not have experience developing or manufacturing fighter aircraft. North American's young and eager company president put the aviation world on notice by offering to design and deliver a more advanced fighter incorporating the latest in technology, exceeding even the very capable P-40 Warhawk produced by the Curtiss-Wright Corporation. Additionally, North American Aviation planned to test the prototype in 120 days. Not only did North American design and deliver the P-51 Mustang, it flew the first flight in 117 days.<sup>12</sup> Unlike how the F-35 acquisition process has become bogged down, the Mustang succeeded quickly because there was urgency to support the warfighter, fierce industry competition, and intellectual sharing among industry, government and academia to produce an advanced platform<sup>13</sup>

### **Copy Cats**

Finally, the cost incurred with developing innovative technology has caused many countries, like China, to pursue industrial espionage as a method to close the technological gap. The cost of stolen technology or "military trade secrets" by

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<sup>12</sup> Alan Haggerty, and Roy Wood. 2010. "THE P-51 MUSTANG: A CASE STUDY IN DEFENSE ACQUISITION." *Defense AR Journal* 17, no. 4: 508-519. *International Security & Counter Terrorism Reference Center*, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=7&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104> (accessed November 22, 2016).

<sup>13</sup> Ibid.

state actors unfortunately levels the playing field for the competition when they lack the ability to conduct their own research and development or create new technologies. Information leaked, exploited through cyber espionage, or acquired from foreign intelligence officers, significantly reduces a country's technological advantages against a peer competitor at a fraction of what it costs the true innovators to produce.

This paper presents four interwoven arguments as it relates to the merits of the F-35. First, it explores exactly how expensive the F-35 is to develop and procure. Second, it examines the value of developing a “Swiss Army knife” type of fighter that can “do it all”, but at what cost? Next, it analyzes whether the most expensive fighter ever developed is truly what the U.S. military needs. Finally, it argues that threats associated with institutional efforts by state actors such as China to acquire advanced technology illegally, negate America’s enormous technological and industrial effort.

## Chapter 2: F-35

*"There is a partly justified criticism that peacetime generals are always fighting the last war instead of the next one."*<sup>1</sup>

*-Colonel Matthew G. Kelly, USMC*

It appears to many that the general officers and flag officers responsible for signing off on the next generation fighter have, in fact, built an advanced aircraft based on projected future threats. This revelation comes in stark contrast when compared to previous generations that seemed to model the next aviation instrument of warfare based on yesterday's battlefield achievements. The U.S. military aviation community touts the F-35 as the future of military aviation, but the program has been plagued with problems going back almost two decades. The question remains, is the F-35 as capable as senior leadership and program managers would lead everyone to believe? The F-35 Lightning II, a 5th generation fighter, is promoted as the answer to the fighter community's problems. The U.S. military expects to purchase 2,457 of them to replace their aging fleet.<sup>2</sup> Additionally, the U.S. has entered foreign military sales agreements and manufacturing contracts with nine countries. Envisioned as the unmatched aircraft modernization program for several post-Vietnam aircraft platforms, the

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<sup>1</sup> Colonel Matthew G Kelly, "The F-35's New OODA loop." U.S. Naval Institute Proceedings 142, no. 3 (March 2016): 24-28. Academic Search Premier, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=9&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104&bddata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=113446263&db=mth> (accessed October 01, 2016).

<sup>2</sup> Ibid., Michael J. Sullivan, "F-35 Joint Strike Fighter." GAO Reports.

JSF has failed to live up to expectations, suffered repeated failures to meet critical design deadlines, and is plagued with software issues.<sup>3</sup>

### **Background**

On October 26, 2001, the Under Secretary of Defense for Acquisition, Technology and Logistics announced the decision to establish the Joint Strike Fighter (JSF) program and named Lockheed Martin as the primary contractor. The F-35 Lightning II is a single engine, single seat, multi-role, 5<sup>th</sup> generation, stealth fighter that incorporates fused sensor information.<sup>4</sup> Four years and four months after naming Lockheed Martin as the primary contractor the first production F-35A rolled out of the factory in Fort Worth, Texas. Finally, in February 2011, the first test flight was conducted, nearly ten years after standing up the JSF program. Despite this milestone, the decision to go to production years before the first test flight was criticized as acquisition malpractice.<sup>5</sup>

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<sup>3</sup> Michael W. Pietrucha, "The Comanche and the Albatross About Our Neck Was Hung," *Air & Space Power Journal* 28, no. 2 (May 2014): 133-156. Academic Search Premier, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=11&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104> (accessed October 03, 2016). This article examines the F-35 and makes recommendations utilizing the failed U.S. Army Comanche program as a reference while arguing the merits of putting so much emphasis on a single platform in the U.S. aviation arsenal.

<sup>4</sup> The author defines a fifth-generation fighter as a fully configured, combat loaded aircraft designed with all aspect stealth, advanced avionics with a capability to network with similar aircraft. The Lockheed F-22 Raptor is the only other US fielded fifth-generation fighter.

<sup>5</sup> Frank Kendall, soon after assuming his current position as the chair as undersecretary of Defense for acquisition, technology, and logistics, told a group assembled on February 6, 2012 which was hosted by the Center for Strategic and International Studies that going to production on the F-35 in advance of completing test flights was acquisition malpractice. Despite efforts to remove the diminished reputation of the F-35 acquisition process, Senator John McCain on January 10<sup>th</sup>, 2017 again referred to the F-35 program as the poster child for acquisition malpractice. <http://www.mccain.senate.gov/public/index.cfm/press-releases?ID=BB1CF636-8EEF-4664-B41C-E87511DA382F> (accessed February 17, 2017)



The F-35 is manufactured in three variants. The USAF will take delivery of the F-35A Conventional Take Off & Landing (CTOL) variant. The Air Force plans to purchase 1,763 aircraft through 2037. The USAF Initial Operational Capability (IOC) occurred August 2016.<sup>6</sup> The F-35B will be operated by the USMC and has the Short Take Off/Vertical Landing (STOVL) capability similar to the AV-8B Harrier. The USMC plans to purchase 340 F-35Bs. The F-35B compromised aerodynamics and range due to a smaller fuel capacity to achieve the vertical take-off capability. The USMC IOC occurred July 2015. Additionally, there are concerns with overheating of the flightdeck on both the Landing Helicopter Dock (LHD) WASP Class ship as well as the Landing Helicopter Assault (LHA) AMERICA Class ship. Both the A and B variants have the same wing span and length; however, due to the STOVL tradeoffs the A variant carries over 5,000 pounds more fuel and has a longer range than the B variant. The US Navy is slated to purchase 260 F-35C Carrier Variant (CV). The Navy is expected to achieve IOC in 2018. The Navy variant has a larger wing and horizontal tail area.<sup>7</sup> Additionally, the CV variant has a tailhook and the ability to fold their wings to maximize the limited room necessary for carrier operations.

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<sup>6</sup> Initial Operational Capability (IOC) is defined as the state achieved when a unit has met minimal deployment capability.

<sup>7</sup> Reuters, "The 11 Countries Expected to Buy the F-35 Fighter Jet," <http://www.reuters.com/article/us-lockheed-martin-canada-f35-orders-idUSKBN0EG2XD20140606> (accessed December 22, 2016).

The original cost of the three variants (USAF, USMC, USN) in 1994 when the program was being developed was \$28 million, \$35 million and \$38 respectively. In today's dollars, the most expensive variant should have cost between \$45 million and \$61 million, instead the price tag is almost twice what was originally planned.<sup>8</sup> Using 2002 dollars, the original flyaway unit cost of the F-35A was projected to be \$37 million, the F-35B was \$46 million and the F-35C was \$48 million. Early production F-35A's had a flyaway cost of \$130 million, significantly more than originally planned. Advance the clock to 2016, the current cost of the F-35A is approximately \$94.6 million per unit, almost three times the original cost of the lowest priced variant. Unit cost is effected by the number of aircraft produced and foreign military sales. The fly away cost for a foreign military model is higher than the price the U.S. pays. Per Lieutenant General Bogdan, the F-35 Executive Officer, the projected future U.S. flyaway cost of the F-35 will decrease to figures between \$80 to \$85 million.<sup>9</sup>

Outside the U.S., eight international partners produce parts for and have placed acquisition orders for the F-35: the United Kingdom, Italy, the Netherlands, Turkey, Canada, Denmark, Norway, and Australia. The

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<sup>8</sup> Mike Fredenburg, "The F-35: Throwing Good Money After Bad Money" *The National Review* (July 22, 2015). <http://www.nationalreview.com/article/421473/f-35-defense-waste-danger> (accessed February 3, 2017).

<sup>9</sup> Kym Bergmann, "F-35 "Misperceptions and Inaccuracies are so Far From the Reality." *Asia-Pacific Defence Reporter* 42, no. 2 (March 2016): 32-34. *International Security & Counter Terrorism Reference Center*, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=13&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104> (accessed December 5, 2016).

governments of Israel, Japan and the Republic of Korea are not part of the supply process, but have agreed to purchase the F-35, helping reduce the overall cost of the aircraft. Within the U.S., Lockheed Martin has F-35 subcontractors located in 45 different states and by some accounts the aircraft falls under a political protection umbrella due to the 133,000 jobs created by the 1,300+ suppliers necessary to field the aircraft.<sup>10</sup>

### **The Good and the Bad**

In spite of developing the next generation of fighter to engage with an equal fifth-generation near-peer enemy fighter while operating in an Anti-Access / Anti-Denial arena trade offs must be made. The F-35 brings both leading edge capabilities while attempting to field immature technical systems that require further testing and evaluation. Critics argue that in a world dominated by drones, the single-seat F-35 is unnecessary.<sup>11</sup> In contrast, the former Chief of Staff of the USAF, General Mark A. Welsh III, remarked during a presentation he gave at the 2013 Air Force Association's Air & Space Conference and Technology Exposition, that with the "F-35, we have no other choice. The issue with F-35 is if you don't have it you can't operate in the advanced air defense systems of the

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<sup>10</sup> Mark Thompson, "The Most Expensive Weapon Ever Built." *Time* 181, no. 7 (February 25, 2013): 26. *Academic Search Premier*, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=15&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=85623603&db=aph> (accessed December 22, 2016).

<sup>11</sup> Kevin Gray, "The last fighter pilot: the new F-35 fighter jet is so sophisticated, so automated, so connected, it's fueling a debate: do pilots still need to fly?" *Popular Science*, 2016., 52, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=21&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104> (accessed September 7, 2016).



future. You can't do it. And you can't compete with the fifth-generation aircraft unless you have a fifth-generation aircraft. It's that simple. You can't dress up an old one and make it a new one. You can make it better, but you can't make it this."<sup>12</sup> Unfortunately, the list of challenges for the F-35 seem as numerous as its proposed capabilities.

Advocates for the F-35 have their hands full defending the merits of such a publicly plagued program. In contrast to the previously discussed challenges, the F-35 may be what the warfighter needs to fight the next war. Many, however, argue that more money should be invested in fighting the current low-tech wars of the last two decades and less money spent on having the most advanced fighter. The last U.S. fighter shot down in an air-to-air engagement was during Desert Storm in 1991. The F-35 has been likened to a "flying Swiss Army knife, able to engage in dogfights, drop bombs and spy."<sup>13</sup> Additionally, the aircraft can defeat tomorrow's threats in both an air-to-air and air-to-ground mode delivering lethality and survivability unlike the current 4<sup>th</sup> generation fighters. The major difference between the generations is the 5<sup>th</sup> generation aircraft survivability in a lethal surface-to-air envelop or a sophisticated anti-access/ area-denial (A2/AD)

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<sup>12</sup> Gen. Mark A. Welsh, Air Force Association's 2013 Air & Space Conference and Technology Exposition. "Air Force Update" 17 September 2013 <http://www.af.mil/Portals/1/documents/af%20events/af130917AFWelshfinal.pdf> (accessed October 3, 2016).

<sup>13</sup> Ibid., Mark Thompson, "The Most Expensive Weapon Ever Built."

sanctuary. It appears the generals got it right this time: The F-35 is poised to fight and win the next war, not the last one.<sup>14</sup>

The argument has been made that the cost of the JSF program is simply too expensive. The fact of the matter is the unit cost per each F-35 is approximately \$109 million and declining with each signed contract. Although that figure is high, the U.S. government has developed aircraft from design to production to combat at a much higher cost. Advanced technology is not cheap to develop and if the U.S. desires to maintain a tactical advantage against one's adversaries it comes with a large price tag. There are six U.S. military aircraft that possess a higher unit cost than the F-35: E-2D \$232 million, VH-71 \$241 million, P-8A \$290 million, C-17A \$328 million, F-22 \$350 million and the B-2 \$2.4 billion. The difference between these programs and the F-35 is the total number to be purchased. The U.S. intends to purchase over 2,400 F-35s in three distinctly and physically different variants. Offering a technical edge to the Navy, the F-35 will be the first carrier-based stealth fighter. The F-35 production run will continue until 2038 and the aircraft is expected to see continued planned operations until 2070.<sup>15</sup>

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<sup>14</sup> Ibid., Colonel Matthew G. Kelly, "The F-35's New OODA loop."

<sup>15</sup> Guy Snodgrass, "U.S. Naval Aviation and Weapons Development in Review," *U.S. Naval Institute Proceedings* 142, no. 5 (May 2016): 84-89. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=3&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213&bdata=JnNpdGU9ZWZlWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=115174744&db=mth> (accessed November 6, 2016).

Despite the criticism that the F-35 has received, it would be unfair to compare the F-35 to any other fighter in existence due to the ability of this 5<sup>th</sup> generation fighter to operate in an Anti-Access / Area Denial (A2/AD) envelope unmolested by enemy surface-to-air weapon systems. For the aircraft to be judged accurately, it cannot be compared to fourth-generation fighters and is often inappropriately compared to the F-16. Unlike fourth-generation fighters, the F-35 does not solely rely upon maneuverability to escape from an adversary. The F-35 has the ability to enter an A2/AD environment, employ its weapons, and depart unmolested, even the F-22 cannot make this claim.<sup>16</sup>

When compared to air-to-air tests against the F-16, critics argue that the F-35 performs poorly in the visual arena aka “the dogfight” due to poor maneuverability. Despite its lack of “dogfighting” capability, the F-35 achieved a positive milestone on Jan 12, 2016 when it fired the first AIM-9X over the Pacific Sea Test Range. The AIM-9X is an infrared missile and the newest version of the Sidewinder family. The 9X is a short-range, air-to-air heat seeking missile capable of being launched off-boresight.<sup>17</sup> This milestone paves the way for further advanced testing using the helmet-mounted cueing system for high off-boresight engagements.<sup>18</sup>

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<sup>16</sup> Further discussion of operating in an A2/AD environment goes beyond the scope and classification of this paper.

<sup>17</sup> Off-boresight as applied to the AIM-9X means the missile can be employed at angles greater than zero degrees on either side of the missile's centerline.

<sup>18</sup> "F-35 Fires First AIM-9X Missile." *States News Service*, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=30&sid=5b9e08b7-0abf-> (accessed November 9, 2016).



The unclassified “critics list” includes: pilots' helmet issues, immature software, and the fact that the aircraft has not fired a weapon. Additionally, the RDT&E and procurement program price tag has nearly doubled since 2001, to approximately \$400 billion which has many worried the cradle to grave price of 1-1.5 trillion dollars may become a reality. Production delays resulted in the USN and USAF spending an additional \$5 billion to extend fleet aircraft to cover the gap. Finally, the “pivot to the Pacific” presents a fuel-distance issue due to a reduced combat radius (584 miles for the USAF and 615 miles for the USN).<sup>19</sup> Furthermore, forward basing presents its own challenges as it relates to the current operational environment. As the nation’s priorities pivot to the Pacific, our most competitive adversary, China, has logistical and range advantages base ere a likely battle would ensue. According to the Department of Defense’s Selected Acquisition Report (SAR) on the F-35 Joint Strike Fighter Aircraft baseline development estimate, the combat radius of the F-35(A) is 679 miles, F-35(B) is 518 miles and the F-35(C) is 690 miles.<sup>20</sup>

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<sup>19</sup> Mark Thompson, “The Most Expensive Weapon Ever Built,” *Time* 181, no. 7 (February 25, 2013): 26. *Academic Search Premier*, <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=15&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104&bdata=JnNpdGU9ZWZlWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=85623603&db=aph> (accessed December 22, 2016).

<sup>20</sup> Department of Defense, “Selected Acquisition Report (SAR), F-35 Joint Strike Fighter Aircraft (F-35)”, December 2015. <https://fas.org/man/eprint/F35-sar-2016.pdf#page=16> (accessed March 28, 2017). Ranges are based on the following configuration: two 1000# JDAMs and two internal AIM-120s, full expendables, execute a 600 foot (450 UK STOV) STO from LHA, LHD, and aircraft carriers (sea level, tropical day, 10 kts operational WOD) and with a combat radius of 450 nm (STOV profile). Also must perform STOV vertical landing with two 1000# JDAMs and two internal AIM-120s, full expendables, and fuel to fly the STOV Recovery profile.

The original plan intended for all three F-35 variants to possess a 70% parts commonality. Unfortunately, the evolution of the aircraft has resulted in a very different picture taking shape. The Joint Project Office lead Lt.Gen. Bogdan, told

Maximum Chinese Air-Launched ASCM Engagement Ranges, 1996 and 2017

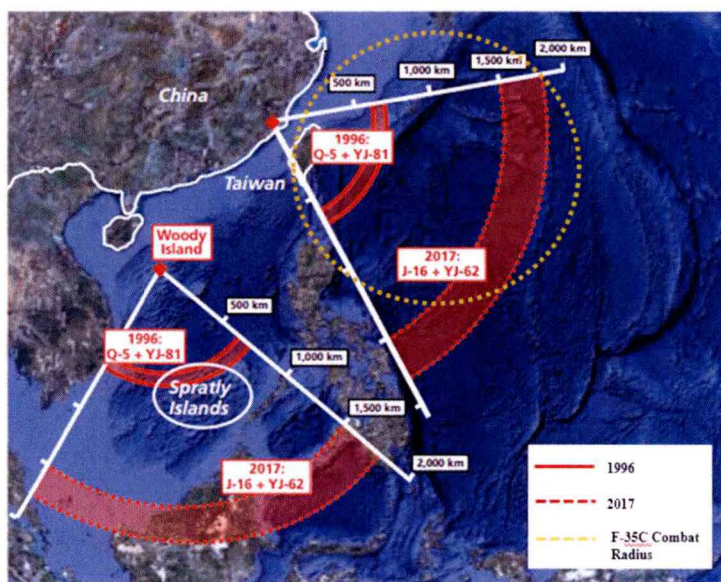


Figure 2. Source: Rand Corporation The U.S.-China military scorecard : forces, geography, and the evolving balance of power, 1996-2017 / Eric Heginbotham ... [and thirteen others with author modification.

a seminar in February 2016 that “the three F-35 models are only 20-30% common, mainly in their cockpits and main sensors. In other words, the JSF is three different

warplanes

affectionately referred

to in certain circles as the F-35, F-36 and F-37.”<sup>21</sup> From a logistic perspective this is problematic due to the additional resources required to be available, which adds to the overall cost to operate the aircraft. As with any new aircraft, unexpected common part failures will be experienced and result in significant demand signals on an already stressed supply system.

<sup>21</sup> Georg Mader, 2016. "Combat Aircraft Update." *Military Technology* 40, no. 6: 36-44. <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=27&sid=5b9e08b7-0abf-4502-a81d-42c510d59863%40sessionmgr107&hid=104> (accessed November 2, 2016).

Those opposed to the F-35 argue that it cannot adequately fill the Close-Air Support (CAS) mission currently being supported by the A-10 Warthog.

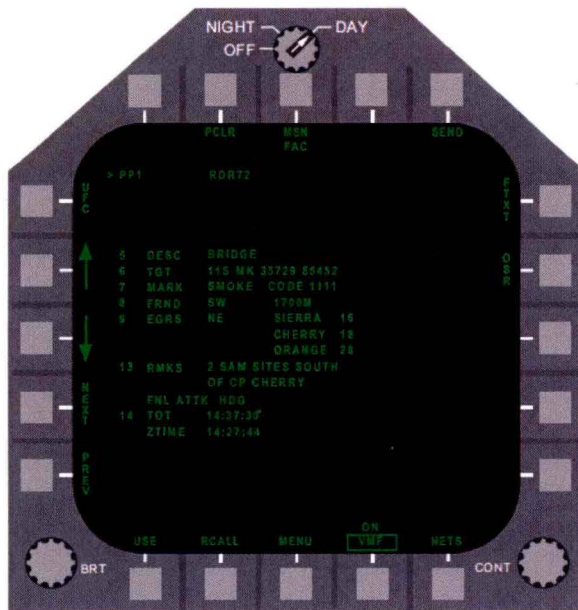


Figure 3 SIMPLIFIED CAS 9-LINE DISPLAY (Basic display by Boeing and modified by Gregory D. Bigalk)

Testifying before the House Armed Services Committee on April 14, 2015, Michael Gilmore, Director, Operational Test, and Evaluation, for the Office of the Secretary of Defense stated the F-35A in the CAS roll only had 45 minutes of loiter time. On-station times are

further complicated based on the enemy's anti-access anti-denial (A2/AD) capability.

Due to the F-35's shorter on station times, tanker support for all variants will be negatively effected due to honoring the A2/AD envelope. In otherwords, the A2/AD threat envelope will prevent tankers from refueling the F-35 close to the enemy's shore. Conversely, the USMC version F-35B, is only capable of 20-30 minutes of useful mission time. Due to the inherent complications with conducting the CAS mission, it is plausible this will negatively impact full execution of time critical targets and put troops at risk. Furthermore, Gilmore offered there were known deficiencies with digital communications in receiving



9-line messages to support CAS and that capability was not yet functional as designed; however, as shown in figure 3, current multi-role aircraft such as the F/A-18 have that capability.<sup>22</sup> Gilmore went on to report that the A-10 in the CAS role typically had an on-station time of 90 minutes – twice the “on station” time of the F-35A and in some cases four times that of the USMC variant. When asked to discuss survivability comparison between the F-35 and the A-10 in the CAS role, Gilmore responded that an F-35 cannot take the hits that an A-10 could take.

Of all the F-35 program faults, the greatest concern lies in its cost. Analyzing its cost drivers, one of the most expensive aspects of the aircraft is the development of stealth technology. At some point cost and capability curves cross and one must ask, is stealth worth the investment or are there other ways of solving the A2/AD problem? What does the U.S. Navy know that no one else does? Even the former U.S. Chief of Naval Operations, Admiral Jonathan Greenert has downplayed the importance of stealth. Greenert, a submarine officer

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<sup>22</sup> Hearing on National Defense Authorization Act for Fiscal Year 2016 and oversight of previously authorized programs before the Committee on Armed Services, House of Representatives, One Hundred Fourteenth Congress, first session: Subcommittee on Tactical Air and Land Forces hearing on update on the F-35 Joint Strike Fighter Program and the fiscal year 2016 budget request, hearing held April 14, 2015. n.p.: Washington : U.S. Government Publishing Office, 2015., <https://www.gpo.gov/fdsys/pkg/CHRG-114hhrg94746/pdf/CHRG-114hhrg94746.pdf> (accessed November 8, 2016). Bigalk, Gregory D., "Implementation of the Digital Communication System in the F/A-18 Aircraft. " Master's Thesis, University of Tennessee, 2002. [http://trace.tennessee.edu/utk\\_gradthes/2029](http://trace.tennessee.edu/utk_gradthes/2029). A CAS 9-Line is a shortened communication method to provide critical details to players on the ground and the delivery platform the game plan for weapons delivery being requested by a Joint Terminal Air Controller (JTAC) or Forward Air controller (Airborne) (FAC(A)).



by trade, further stated, “stealth may be overrated or may become further mitigated. If you move through the air fast that puts out heat and emissions, you are going to be detected. Therefore, the value of air-to-air (ATA) and air-to-surface (ATS) weapons hitting ever further away will continue to gain in future conflicts.” Stated another way, Greenert referred to advances in capability that would further detect stealth technology enabling the advisory to employ weapons at greater ranges.<sup>23</sup> The CNO’s words have matched his actions. The U.S. Navy has reduced the number of F-35C’s by one third and invested \$800 million into long-range standoff weapons.<sup>24</sup>

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<sup>23</sup> The term “stealth” as applied in this paper does not imply an aircraft is invisible to enemy radar. It simply means the aircraft has a Low Observable (LO) aircraft signature and is optimized to defeat higher-frequency radar bands.

<sup>24</sup> Georg Mader, “In a Kill Zone Far, Far Away ..” *Military Technology* 39, no. 6 (June 2015): 63-68. <http://eds.a.ebscohost.com.ndueproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=1&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213> (accessed November 2, 2016).

### Chapter 3: F-22

The Lockheed Martin F-22 Raptor was the first 5<sup>th</sup> generation fighter and is the single most advanced and capable air-to-air platform in existence. With an original planned production run of over 750 aircraft, Secretary of Defense Robert Gates in 2009 prematurely cancelled the program stopping production at 187 aircraft.<sup>1</sup> Gates offered that he felt the aircraft provided little in the effort of fighting today's wars or the scenarios likely to be faced by the U.S. in the coming years.<sup>2</sup> Gates' argument could clearly be applied to the overall number of F-35's as well. One could offer a compromise in purchasing both a smaller number of F-35s and a larger number of F-22's, while conducting incremental improvements to existing aircraft. The Raptor is a state-of-the-art aircraft and the first fighter to possess stealth technology and the ability to achieve "super cruise" capability.<sup>3</sup>

An equally important question is, if the F-35 has so many problems and the F-22 is too expensive, what does the 6<sup>th</sup> generation fighter look like? Will the next generation fighter look like the F-22, just cheaper? Due to classification issues, that information will not be discussed in this paper; however, if the sixth-

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<sup>1</sup> "A 5<sup>th</sup> Generation Fighter: What Does it Mean?." *Airforce Magazine* 36, no. 3 (September 2012): 35-39. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=12&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213> (accessed November 7, 2016).

<sup>2</sup> Ward Carroll, "Secretary Gates and the F-22 Raptor", April 15, 2015. <http://www.defensetech.org/2009/04/15/secretary-gates-and-the-f-22-raptor/> (accessed December 22, 2016).

<sup>3</sup> Super cruise flight is defined as the ability to fly at supersonic speeds for extended periods without the use of afterburners. An afterburner is an auxiliary power source that provides extra thrust by injecting fuel into the engine's hot exhaust gasses and burning it.

generation fighter does look like an F-22, this hypothetically opens a door to the argument of reopening the F-22 production line. There are many physical challenges associated with opening the F-22 aircraft line, the least of which is how. One could offer that Lockheed could expand their production line to include F-22's. Many of the required support requirements are in place vice building a new facility, which might be cost prohibitive. The argument against reopening the production line is that Lockheed Martin is the primary contractor to both the F-35 and the F-22 and it may pose a financial conflict of interest to their stockholders due to the proposed production rate of the F-35. As it stands today, it is unlawful to export the F-22 and Lockheed Martin is fully aware that if that law stays in place the only customer would be the USAF. It is unrealistic to believe a production run would be for more than 300 aircraft, which would result in a high flyaway cost. The former Air Force Chief of Staff, General Mark Welsh III stated in July 2016 prior to his retirement that "reopening the F-22 manufacturing line may cost less than developing a whole new fighter."<sup>4</sup> Where the F-35 suffers, the F-22 shines. A high-low mix of F-22's and F-35s respectively will maintain our tactical advantage against a near peer adversary. Combining capabilities such as super-cruise without afterburner, thrust vectoring,

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<sup>4</sup> Jon Harper, "F-22 Restart Might Not Be Beneficial for Lockheed Martin." *National Defense* C1, no. 752 (July 2016): 36-38. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=15&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213>. (accessed December 5, 2016).

and supermaneuvrability, while offering a clear picture of the battlefield due to fused data, is what makes American air superiority peerless.

### **F-22 Has Warts**

The argument can be made that for all the positive press associated with the F-22, there are several serious drawbacks. First, the F-22 does not have a short field take-off capability nor can it operate off carriers, which limits its operations strictly to secure bases. Due to these shortfalls, there is not a capability to sea base. The F-22 requires allies to authorize the forward basing of assets or cause long-range flights with numerous air-to-air refueling requirements. Next, the F-22 has a very narrow set of roles and is limited to utilization by one service. Since the aircraft was deemed unlawful for export due to the advanced capabilities at the time of inception, only one nation can assist with the cost share. Additionally, due to a lack of availability both the USMC and USN have limited integration experience with the F-22 except during large annual large force exercises. From a mission planning perspective, unless there is an advocate during operations planning or a USAF liaison officer embarked on the U.S. carrier little to no consideration would be given to adding this asset during planning cell discussions. There are simply too few aircraft available for other services to become familiar with the F-22.

### **F-22 Improvements**

The F-22 is not without its own improvements since its inception. While the F-22 was optimized for the air combat role, it lacked a ground-attack capability.



The first modernization program, called "Increment 2," added the capability to employ two 1,000-lb. GBU-32 JDAM (Joint Direct Attack Munitions) contained in the internal weapons bay. In 2007, the APG-77(V)1 radar systems were upgraded to include an air-to-ground capability. The enhanced radar system improvement allowed crews to reprogram JDAMS in flight if emerging targets or time critical targets presented themselves. The enhancement enables the F-22 to detect emerging ground targets and retarget JDAMs in flight, rather than restricting them to release on only pre-planned coordinates. Improvements in the air-to-ground arena continued with the release of increment 3.1 in 2012 and were retrofitted across the fleet.

The latest improvement enables F-22 crews to employ up to eight GBU-39 small diameter bombs for missions that require more precision bombing. The GBU-39 is a 250-lb multipurpose, insensitive, penetrating, blast-fragmentation warhead for stationary targets. The GBU-39 is equipped with wings that deploy to extend the standoff distance. In March 2016, the first Raptors were configured with the AIM-9X Sidewinder.<sup>5</sup> Installation of this latest incremental improvement is scheduled for completion in mid-2017."<sup>6</sup> In September 2014,

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<sup>5</sup> Guy Norris, "Small Wonder." *Aviation Week & Space Technology* 167, no. 14 (October 8, 2007): 35. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=17&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213&bdata=JnNpdGU9ZWZlWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=27454738&db=aph> (accessed November 9, 2016).

<sup>6</sup> Dan Katz, "F-22 Raptor." *Aerospace Daily & Defense Report* 250, no. 42 (December 4, 2014): 7-9. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=19&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213> (accessed November 9, 2016).

after nine years of sitting on the sidelines the Raptor conducted its first combat mission against the Islamic State of Iraq and the Levant (ISIL) conducting strikes on enemy ground targets.<sup>7</sup> As of July 2016, the USAF Raptors deployed out of Al Dhafra airbase, UAE are engaging against Daesh in Syria utilizing the most advanced software available, increment 3.1 and can employ the GBU-39 or the GBU-32 as necessary.

The added value of a high kill ratio adds to the significant value of integrating F-22's in an air superiority role combined with the F-35. In a fight with a near-peer competitor, the USAF and Lockheed Martin estimate if an F-22 fought against a Russian SU-27 or MiG-29 the loss-exchange ratio would be 30:1. Phrased differently, 30 Russian SU-27 or MiG-29 would be shot down in combat versus the loss of a single F-22. In contrast, the F-35 has a 3:1 kill ratio while U.S. fourth-generation fighters have a 1:1 or less ratio against the Russian Su-27 and MiG-29.<sup>8</sup> In addition to providing unquestionable air-to-air protection for the F-35, the added capability of GBU-39's to the F-22 enable the Raptor to be employed as a swing fighter if necessary. As a swing fighter, the F-22 can deploy air-to-ground weapons if air-to-air engagements become unnecessary. For its few

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<sup>7</sup> "F-22 Raptor Brings Unique Capabilities to the Coalition Fight Against ISIL," *States News Service*, September 29, 2014. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=25&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=edsgcl.384078625&db=edsgbc> (accessed November 2, 2016).

<sup>8</sup> David A. Fulghumid, "RAPTOR'S EDGE," *Aviation Week & Space Technology* 170, no. 6 (February 9, 2009): 24-26. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=22&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=36807845&db=edb> (accessed November 2, 2016).

problems, the F-22 looks like a valuable partner to the F-35. While it supports the F-35 in a 5<sup>th</sup> generation high-low mix, it cannot do everything. That said, there are other aircraft with necessary capabilities whose service life may be extended to meet the needs at a cheaper cost than just buying more F-35's.

## Chapter 4 Incremental Success Programs

The USAF's choice to modernize the B-52 serves as just one of many success stories as it applies to upgrading proven airframes. The Boeing B-52 Stratofortress, affectionately referred to as the BUFF Big Ugly Fat Fellow, first flew in 1952 and became an active member of the USAF arsenal in 1955. Based on upgrades in 2015, the B-52 is scheduled to fly until 2044 - 89 years of proposed service life based on upgrades as late as 2015.<sup>1</sup> Originally designed as part of the US nuclear deterrence program and fitted to carry nuclear weapons, the aircraft has participated in every major conflict from Vietnam in 1965 to Operation INHERENT RESOLVE in 2016.<sup>2</sup> The United States Air Force maintains 76 B-52H nuclear-capable aircraft at two bases within the United States.<sup>3</sup> Although the airframe has gone through significant retrofits and modernization, Northrop Grumman Corporation has been awarded the contract to build the B-21 Long Range Strike Bomber (LRSB) to replace the B-52.<sup>4</sup> The LRSB is scheduled to meet their Initial Operating Capability in 2025.<sup>5</sup>

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<sup>1</sup> US Air Force, "B-52 Stratofortress," December 16, 2016, <http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104465/b-52-stratofortress.aspx> accessed (October 27, 2016).

<sup>2</sup> Ibid., US Air Force, "B-52 Stratofortress,".

<sup>3</sup> Amy F. Woolf, "B-52 Bomber." Congressional Research Service: Report (September 27, 2016): 30-34. <http://eds.a.ebscohost.com.ndueproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=27&sid=a9fdc72b-09e2-460e-a90a-767e1ebdfa39%40sessionmgr4008&hid=4213> (accessed October 03, 2016).

<sup>4</sup> Harold Hutchison, "Good Bye B-52 Stratofortress – A New American Long Range Bomber Is A Reality," The Daily Caller, October 28, 2015. <http://dailycaller.com/2015/10/28/good-bye-b-52-stratofortress-a-new-american-long-range-strike-bomber-is-a-reality/> (accessed Oct 3, 2016).

<sup>5</sup> Colin Clark, "Coating Plant Offers Hints on B-21 Production", Breaking Defense, February 6, 2017, <http://breakingdefense.com/2017/02/coatings-plant-offers-hints-on-b-21-production/> (accessed February 15, 2017).



The B-52, an unmistakable symbol of U.S. military power, has been showcased over the years by the U.S. government. A demonstration of American strength was displayed in South Korea days after North Korea claimed they had tested a hydrogen bomb. The military “show of power” provided by the Stratofortress was flanked with South Korean F-15s and U.S. F-16’s as a visual deterrent to North Korea.<sup>6</sup> The B-52 remains a glowing example of how incremental improvements to a viable platform can maintain its relevance on the modern battlefield.

#### **F-16 STAR Program**

An additional factor to consider when conducting an analysis of incremental improvements to an aircraft is the extension of the lifespan of an aircraft. A holistic view must be considered when addressing inventory management challenges. Technological improvements that make the aircraft viable on the battlefield are just one consideration, equally important is the life cycle of an aircraft. Strong consideration should be given to the safety of the aircrew and maintainers while weighing the risks when extending the manufactures expected life cycle without repair or entering aged aircraft into a service life extension program.<sup>7</sup> Furthermore, utilizing an “hour based” determination for rework does

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<sup>6</sup> Holly Yan, Will Ripley. January 10. 2016. U.S. B-52 bomber flies over S. Korea in solidarity after N. Korean nuclear claim. <http://www.cnn.com/2016/01/10/us/b-52-south-korea/> (accessed December 22, 2016).

<sup>7</sup> There are three major factors that limit the service life of a fleet aircraft: structural fatigue, challenges in obtaining system support and the weakening comparative capabilities.

not offer a complete picture on the structural integrity of the aircraft because each sortie does not apply the same level of stress on the airframe.<sup>8</sup> The F-16 Structural Augmentation Roadmap (STAR) program was designed to repair and replace critical airframe parts on the F-16. The STAR program effectively extended the 4,000-hour service life cycle on the aging F-16 to 8,000-hours.<sup>9</sup> The F-16 over time has evolved into an all-weather, supersonic, multirole air superiority fighter that would greater complement the F-35 fleet. The STAR program reworked 533 of the 840 F-16s in the USAF fleet at a cost of \$465 million.<sup>10</sup> For the price of less than five F-35A's, 533 versatile and combat proven F-16 fighter aircraft had their life renewed for 16 extra years.<sup>11</sup>

#### **F/A-18 SLEP**

Due to the six year delay caused by repeated setbacks in production of the F-35 which was to replace the U.S. Navy's strike fighter aircraft, the Navy was forced to develop a way to cover the gap. Very similar to the F-16 STAR program, the U.S. developed a Service Life Extension Program (SLEP) for the

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<sup>8</sup> Alan C. Pentz, May 17, 2015. "A Service Life Extension (SLEP) Approach to Operating Aging Aircraft Beyond Their Original Design Lives". <http://pqdtopen.proquest.com/doc/1671782046.html?FMT=AI> (accessed Nov 22, 2016).

<sup>9</sup> U.S. Government Accountability Office (GAO), "Tactical Aircraft: Air Force Fighter Reports Generally Addressed Congressional Mandates, but Reflected Dated Plans and Guidance, and Limited Analyses", February 24, 2011, <http://www.gao.gov/assets/100/97315.html> (accessed November 20, 2016).

<sup>10</sup> Hilltop Times., "Ogden ALC finishes F-16 Falcon Star Program", June 5, 2014 <http://www.hilltoptimes.com/content/ogden-alc-finishes-f-16-falcon-star-program> (accessed November 16, 2016).

<sup>11</sup> Extended life expectancy calculated by utilizing 250 hours per aircraft per year. This calculation is based on 2016 Low Rate Initial Production 10 (LRIP) unit cost of \$94.6 million per each F-35A aircraft. Conversely, 2016 LRIP 10 for F-35B is \$122.8 million and F-35C is \$121.8 million per aircraft. <http://www.defensenews.com/articles/pentagon-lockheed-sign-f-35-contract-for-90-jets> (accessed March 3, 2017).

F/A-18A-D Hornets with a 6,000 hour life cycle plan.<sup>12</sup> On average, a military aircraft could expect to log 250 hours annually. At that rate, an F/A-18 was expected to have a service life of 24 years. To cover the shortfall due to the delayed introduction of the F-35, many F/A-18 aircraft will require another service life extension upwards toward 10,000 hours.<sup>13</sup> Boeing, the original manufacturer of the F/A-18, working closely with the Hornet program office, conducted analysis to determine what common components are “life limiters” and developed a “SLEP Kit”. The SLEP modification kit cost approximately \$2.9 million and it is expected that only 150 F/A-18 Hornets will require the kit. The additional extension would add 16 more years of service life per aircraft, which should provide plenty of overlap to as the F-35 enters the fleet. Finally, the military should move away from utilizing an hours-based threshold or aircraft flight cycle measurement to determine airworthiness as it applies to programs such as SLEP and STAR. Instead, consideration should be given to investigating inherent damage tolerances as well as fatigue capability of the aircraft.

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<sup>12</sup> The 6,000 hour life-cycle represents the “cradle to grave” life expediency of the aircraft. After 6,000 hours, the aircraft could be removed from the inventory.

<sup>13</sup> Daniel P. Taylor, “Keep Them Flying,” *Sea Power* 59, no. 4 (May 2016): 20-22. <http://eds.a.ebscohost.com.nduezproxy.idm.oclc.org/eds/pdfviewer/pdfviewer?vid=1&sid=e740b39e-b1d8-4e71-b844-6e47d8038a21%40sessionmgr4010&hid=4213> (accessed December 16, 2016).

## Chapter 5    Wake Up America

*“Never attempt to win by force what can be won by deception.”*  
-Machiavelli

On June 22, 2015, the USAF and RAND Corp hosted the inaugural China Aerospace Studies Institute (CASI) conference. The keynote speaker was Deputy Secretary of Defense Robert Work who stated, “China is mounting a serious aerospace challenge against the United States and they intend to close the gap. China also is developing stealth aircraft, intelligence, surveillance and reconnaissance and battle-management platforms, advanced air-to-air and air-to-surface missiles... in other words we have to think about the nature and character of air battle 2.0.”<sup>1</sup> Concern has been rising since the public release of information by China on what they claim to be their own indigenous 5<sup>th</sup> generation fighter. A large portion of the funding for the F-35 was predicated on fears that China was aggressively expanding their military capability. The message to Congress and the American public was the U.S. needed to act if they wanted to maintain the tactical advantage when it came to air superiority. Is China truly a near-peer

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<sup>1</sup> Cheryl Pellerin, “Work: Institute to Help U.S. Meet China Aerospace Challenge), DoD News, Defense Media Activity , June 23, 2015, <http://www.defense.gov/News/Article/Article/604870/work-institute-to-help-us-meet-china-aerospace-challenge> (accessed November 20, 2016). Air battle 2.0 is a reference to air sea battle (ASB) 2.0. Admiral James G. Foggo states “the Air-Sea Battle Concept is designed to assure access to parts of the ‘global commons’ – those areas of the air, sea, cyberspace, and space that no one ‘owns,’ but which we all depend on – such as the sea lines of communication. Our adversaries’ anti-access/area denial strategies employ a range of military capabilities that impede the free use of these ungoverned spaces. In short, it is a new approach to warfare.” <http://thediplomat.com/2013/11/air-sea-battle-2-0-a-global-a2ad-response/> (accessed October 22, 2016).



competitor in the air-to-air arena or have they simply produced a paper tiger in the shape of a Chinese J-20 fighter?

Steady economic growth in China has led to the development of the second-largest economy in the world. With economic prosperity, China has aggressively attempted to modernize their ability to project power to both their neighbors and to their West. In 2009, General He Weirong, commander of the People's Liberation Army Air Force, announced that China would field a 5<sup>th</sup> generation fighter in 2017.<sup>2</sup> In addition to the numerous technical challenges the U.S. experienced, which are common with new aircraft designs, the DoD is also dealing with an equally concerning problem of hackers stealing military secrets related to the F-35. One such breach in software allowed the Chinese to steal plans for over two dozen US weapon system programs, including the F-35 *Lightning II* Joint Strike Fighter, B-2 *Spirit* stealth bomber, and the F-22 *Raptor*.<sup>3</sup> These breaches occur too regularly and weaken the U.S.'s technological advantages with each occurrence. The Chinese indigenous J-20 fighter, which conducted its first test flight in 2011, is a copy of the F-22 Raptor, which entered service in 2005. To rival the US development in 2006 of the F-35, the Chinese established the J-31 program in 2012. The J-31, minus propulsion, is a replica of

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<sup>2</sup> Kyle Mizokami. "China Has Big Plans For Its Deadly New Stealth Fighter." November 4, 2016. <http://foreignpolicy.com/2016/11/04/china-has-a-plan-for-its-deadly/> (accessed October 16, 2016).

<sup>3</sup> Ellen Nakashima, "Following US indictments, Chinese military scaled back hacks on American industry." *Washington Post* 30 Nov. 2015 <https://www.highbeam.com/doc/1P2-39029109.html>. *Washington Post* 30 Nov. 2015. (accessed September 16, 2011).

the F-35. These “replicas” make it clear that China has used digital espionage to advance its aircraft design by at least a decade if not more without requisite time and investing the resources. The United States must put more than a thumb in the dike if they want to stop the flow of critical information from falling into the wrong hands.

But not everyone is concerned. The US Air Force Chief of Staff, Gen. David Goldfein said in August, "When I hear about the F-35 vs. J-20, it's almost an irrelevant comparison." The J-20 has been compared to the F-22 and F-35 due to shared physical characteristics, the actual internal avionics and propulsion capabilities have been deemed questionable. The Chief of Staff for the Air Force compared the Chinese aircraft more in terms to the retired F-117 Nighthawk due to the limited capability the aging aircraft possesses. He further explained, unlike the F-35, which integrates with other weapon systems, the J-20 was more in line with the F-117, which lacked external communication when the aircraft flew into combat.<sup>4</sup>

There has been much speculation how China built only their second indigenous aircraft so quickly. Many have speculated China engaged in corporate espionage and stole trade secrets. When asked by Congress, Defense

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<sup>4</sup> Colin Clark, "China's J-20 Vs. F-35? Meh, Says CSAF Goldfein; Pilot Crisis Noted", <http://breakingdefense.com/2016/08/chinas-j-20-vs-f-35-meh-says-csaf-goldfein-pilot-crisis-noted/> (accessed November 16, 2016).

Undersecretary for Acquisition Frank Kendall reported that Chinese hackers had only acquired unclassified information and the concern for F-35 program secrets was unfounded. On the other hand, there were claims there was a breach and the Chinese had in fact acquired significant trade secrets.<sup>5</sup> In a separate case, the J-31, which has a striking resemblance to the F-35, is believed to be a copy fabricated by Chinese corporate espionage. It is believed that China was behind a 2009 cyber intrusion where “huge amounts of design and electronic data on the F-35 were stolen.”<sup>6</sup> Both the Pentagon and Lockheed Martin maintain no classified information was compromised.<sup>7</sup> Accusations to the contrary have been made that as far back as April 2009 Chinese hackers breached Lockheed Martin’s computer network and were able to download blueprints for the F-35.<sup>8</sup> An amateur aviation enthusiast could easily identify the similarities between the U.S. F-35 and the Chinese FC-31. Experts counter that although there are physical similarities, there are enough differences in design that the F-35 was the superior build.<sup>9</sup>

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<sup>5</sup> Justin Ling, “Man Who Sold F-35 Secrets to China Pleads Guilty,” Vice News, March 24, 2016, accessed September 3, 2016, <https://news.vice.com/article/man-who-sold-f-35-secrets-to-china-pleads-guilty> (accessed November 9, 2016).

<sup>6</sup> David Alexander, “Theft of F-35 design data is helping U.S. adversaries -Pentagon”, Jun 19, 2013 <http://www.reuters.com/article/usa-fighter-hacking-idUSL2N0EV0T320130619> (accessed October 11, 2016).

<sup>7</sup> Defensetech, “Did Chinese Espionage Lead to F-35 Delays?” February 6, 2012, <http://www.defensetech.org/2012/02/06/did-chinese-espionage-lead-to-f-35-delays>. (accessed October 3, 2016).

<sup>8</sup> The Diplomat, “China Displays New 5th Generation Stealth Fighter” States News Service, November 10, 2015. <http://thediplomat.com/2015/11/china-displays-new-5th-generation-stealth-fighter/> (accessed November 2, 2016).

<sup>9</sup> Ibid., The Diplomat, “China Displays New 5<sup>th</sup> Generation Stealth Fighter”

## **Chapter 6    Lessons Learned and Recommendations**

By any standard, the F-35 program office has developed the most advanced fighter the world has ever seen. Qualifying its performance, however, is likely many years away and will be validated not over the skies of a California test range, but under combat conditions. If the F-35 remains wrapped in “bubble wrap” like the F-22 did for so long, it will take almost a decade before it is utilized in combat.<sup>1</sup> One of the many advantages the F-35 possesses is its ability to complement the F-22 and fourth-generation fighters much like how the U.S. employed the F-15 Eagle and F-16 Fighting Falcon.

The U.S. should maintain the “high-low” approach to air defense similarly to their approach utilizing the F-15 as the air superiority aircraft and the F-16 as attack platform. Training to this model of warfare, the U.S. should employ the F-22 in the same fashion while enabling the F-35 to operate unmolested in both an air-to-air mode as well as operating with impunity in a medium to high surface to air threat envelope. Despite the F-35’s numerous capabilities, it has yet to prove its superior air-to-air capability. Since Russia has not developed a 5<sup>th</sup> generation fighter, China remains the closest near-peer air threat.

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<sup>1</sup> The author speculates due to the inherent value of marketing a proven commodity, the U.S. will aggressively attempt to be the first country to employ the JSF in combat to capitalize on additional foreign military sale contracts to aid in lower the procurement cost of the JSF.



The following are recommendations based on a comprehensive approach to air warfare for the next twenty years. After careful Congressional review and analysis, reopening the Lockheed Martin F-22 production line is in the best interest of the U.S. Clearly, world dynamics have changed since 2009 when Secretary Robert Gates stopped production of the F-22 at 187 aircraft. It is imperative the intelligence community brief the Senate Armed Service Committee on the latest threat posed by China to better assess the U.S. requirements to maintain air superiority for the next thirty years. Congress has ordered an investigation into the feasibility of reopening the F-22 production line.<sup>2</sup> The costs associated with reopening the production line will not be inexpensive, but clearly cheaper and quicker than constructing an entirely new air superiority aircraft that would complement the F-35. Furthermore, the strategic messaging to Beijing will not be lost in translation. Despite the enormous cost associated with reopening the F-22 line, it will pale in comparison to what it will cost on the world stage if the U.S. is unable to maintain air superiority.

Lockheed Martin, the primary contractor for both U.S. 5<sup>th</sup> generation fighters has little to lose if the F-22 line is not reopened due to internal financial competing interests. The F-35 is already in full production, opening the F-22 line may become a distraction for Lockheed Martin or cause their current production

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<sup>2</sup> As of the submission date of this paper, the findings of the Congressional review have not been provided to the public.

numbers to decrease. To reduce the overall cost of reopening the F-22 production line, the U.S. must aggressively pursue changing the laws that prohibit exporting the aged technology inherent within the first true stealth fighter. As previously discussed, it is unlawful to sell this technology so legislation must be changed to revoke this barrier to help offset the flyaway cost associated with reopening the production line. There must be a financial incentive for Lockheed Martin to invest additional capital into reopening a legacy production line. Consideration should be given to having another major aircraft company such as Northrup Grumman or Boeing assist in helping reopen the F-22 line. It is unorthodox to pass primary aircraft production to a competitor; however, the benefits of increased manufacturing jobs appear to be aligned with President Trump's economic initiative to get more American's working and would aid in rapid production.

Much of the fanfare about the F-35 has been tied to the massive cost of the aircraft, which has garnered significant attention from the Senate Armed Service Committee and President Trump.<sup>3</sup> The pressure imposed by these two government entities has been a forcing function to both Lockheed Martin and the F-35 Program Office to reevaluate the overall cost and explore savings measures to reduce unit cost of the aircraft. One initiative to reduce the overall cost of the

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<sup>3</sup> Christopher Drew. 2017. "Lockheed Lowers F-35 Price, After Prodding by President." *The New York Times*, 2017. B5. <https://www.nytimes.com/2017/02/03/business/lockheed-lowers-price-on-f-35-fighters-after-prodding-by-trump.html>, (accessed February 21, 2017).

aircraft seems to come in the form of simulators. To assist in extending the lifespan of the F-35, the military has reduced the planned annual flight hours per aircraft from 300 hours down to 250 hours. The reduction of 50 annual hours per aircraft adds an additional six years of useful life to the airframe. To those that do not fly it may appear a great compromise; however, most aviators will attest that a vital aspect of training is lost in the simulator due to a lack of adequate actual pressure that comes with flying a live aircraft.<sup>4</sup> A simulator is unable to properly replicate the real-life adrenaline a pilot experiences. During a simulated event, it is impossible to duplicate a situation where the pilot is fearful of losing the aircraft or aircrew. Aircrew are not without stress in the simulator but in the end, if a bad situation develops, aircrew know they can stop, freeze, or simply survive the situation and walk away no matter their actions or inactions. In real life, a pause button or reset switch does not exist and the aircrew must work through whatever emergency or causality they experience. Critics counter that argument by saying it is cheaper to train in a simulator due to more dense threats and longer shot windows. Increased missile and radar ranges have significantly expanded the necessary air space requirements to properly execute the latest tactics. A high fidelity simulator has its place in the training continuum by exposing crews to

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<sup>4</sup> Rich Gillian, "Lockheed's F-35 To Fly Fewer Hours Annually, Extending Life Cycle." *Investor's Business Daily*, March 24, 2016., <http://eds.b.ebscohost.com.nduezproxy.idm.oclc.org/eds/detail/detail?vid=1&sid=7fe84103-999d-41ef-9156-72b650ed117d%40sessionmgr103&hid=104&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=113949201&db=bwh> (accessed December 22, 2016).

robust threats that crews rarely experience but it does not capture all the necessary values associated with a real flight. To say anything contrary simply marginalizes both the lives of the aircrew and jeopardies strategic landscape gained by maintaining air superiority.

There are four primary reasons why the U.S. should limit the modernization of their fleet aircraft and invest in incremental improvements to legacy aircraft. First, there are indications the 2,400-aircraft purchase order of F-35's may be in jeopardy and legacy aircraft will be key to the U.S. maintaining a tactical edge. If the U.S. fails to challenge their industry partners to continue to develop incremental improvements, the aircraft will lose their tactical relevancy and provide limited value in a battle for superiority. Secondly, the F-22 is a proven airframe that possesses greater capabilities than first envisioned. Reopening the F-22 line, even at a significant cost per unit price is imperative from a tactical employment perspective. When production was halted at 187 F-22's, DOD failed to appreciate that the F-35 was not designed to be an air superiority aircraft and lacked the advanced capabilities that make the F-22 the fighter of choice in an air-to-air engagement. Ultimately, the F-35 alone lacks the ability to provide adequate "high" cover in a contested environment. Combining the air superiority of the F-22 with the advanced capability of the F-35's to operate in an A2/AD contested environment unmolested should be the driving factor to increase F-22 production. Finally, the F-35 is not an adequate CAS aircraft. Keeping cheaper



but more capable CAS platforms like the A-10 and F-16 are a force multiplier. Eventually, a golden BB will find its mark and take down a stealth aircraft like the F-35, potentially compromising advanced technology. Platforms such as the A-10 are much more survivable in those environments and have a proven record of performance both in capability and extended on station times compared to the F-35.

Future recommendations: The U.S. government should never let a single contractor be the sole source for a program this large. Due to the varying design requirements by each service a different contractor should have been selected. Since there was a lack of competition after the bid process there was a serious lack by Lockheed Martin to stay on schedule and within budget. The OUSD AT&L should have contracted a separate USMC aircraft requirement due to the number of engineering redesigns, challenges and compromises necessary to make the standard F-35 a vertical launch capable aircraft. Furthermore, a single basic design for the USAF and USN F-35 variants under two different aircraft manufactures would likely have resulted in healthy competition by all three developers potentially resulting in airframes delivered on time and on budget.

### **Conclusion**

The continued development of advanced aircraft technology is necessary if the U.S. wants to maintain a tactical advantage on the modern battlefield. What America has gotten away from is the competitive motivation to quickly design,

test and field an advanced aircraft similar in fashion to how the P-51 Mustang was procured for both the British and the U.S. tipping the scale for a decisive victory in World War II. Since 2001 when Lockheed Martin was awarded the X-35 contract, the JSF has continued to evolve and has become so complicated it will be decades before all its potential is fully developed. If the U.S. wants to maintain their status as the sole superpower, it is essential the U.S. continues to develop advanced airborne systems. Conversely, it is negligent for DOD to allow a process to take decades to field, become years behind schedule, and approach nearly twice the originally estimated cost.

Many concerns have been raised about putting too much emphasis on a single platform. The potential for failure is much higher when too much importance is placed on fielding a single platform to fight the nation's future wars. By spreading various tactical aviation platforms strategically across the battlefield, it will induce confusion due to the wide array of tactics employed by the various legacy aircraft. It is important that the U.S. keeps her enemies guessing as to what airborne threat they may encounter. If the U.S. platform characteristics are all the same, it removes some of the guess work from our adversaries. Additionally, if structural, hardware, or software problems develop, most the force will be negatively affected. That is to say, if a defect or critical failure is experienced it is plausible the entire fleet of F-35's across all services may be grounded.

In addition to fielding advanced aircraft such as the F-35, maintaining a significant number of legacy fighters modernized with leading edge incremental improvements will enable the U.S. to diversify their fleet, remove the potential of single point failure, and maintain a strategic advantage on the battlefield.

Although the U.S. should stay prepared for an all-out war against a near-peer adversary, there is little to be gained by flying a 100-million-dollar fighter to deliver a 500-pound bomb against a low-tech enemy such as ISIL when a cheaper, but capable F-16 could easily deliver it for much less cost.





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## **VITA**

Most recently, CDR Trent served as the Commanding Officer of VAW-125, the first fleet squadron of E-2D Advanced Hawkeyes stationed at Norfolk, Virginia. During his tour, he deployed with the USS THEODORE ROOSEVELT (CVN 71) Carrier Strike Group as part of Carrier Air Wing ONE (CVW-1) in support of Operation INHERENT RESOLVE. While deployed, the squadron showcased the Advanced Hawkeye in combat for six consecutive months and completed an around the world deployment. For their efforts, the squadron was awarded the Commander, Naval Air Forces 2015 Battle Efficiency Award.